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WA102 and Meson Spectroscopy

It may be relevant to the PD

... a short reminder.

Problem:

We expect various types of color singlet mesons;

$|q\bar{q}\rangle$ + … quarkonia,

$|q\bar{q}g\rangle$ + … hybrids

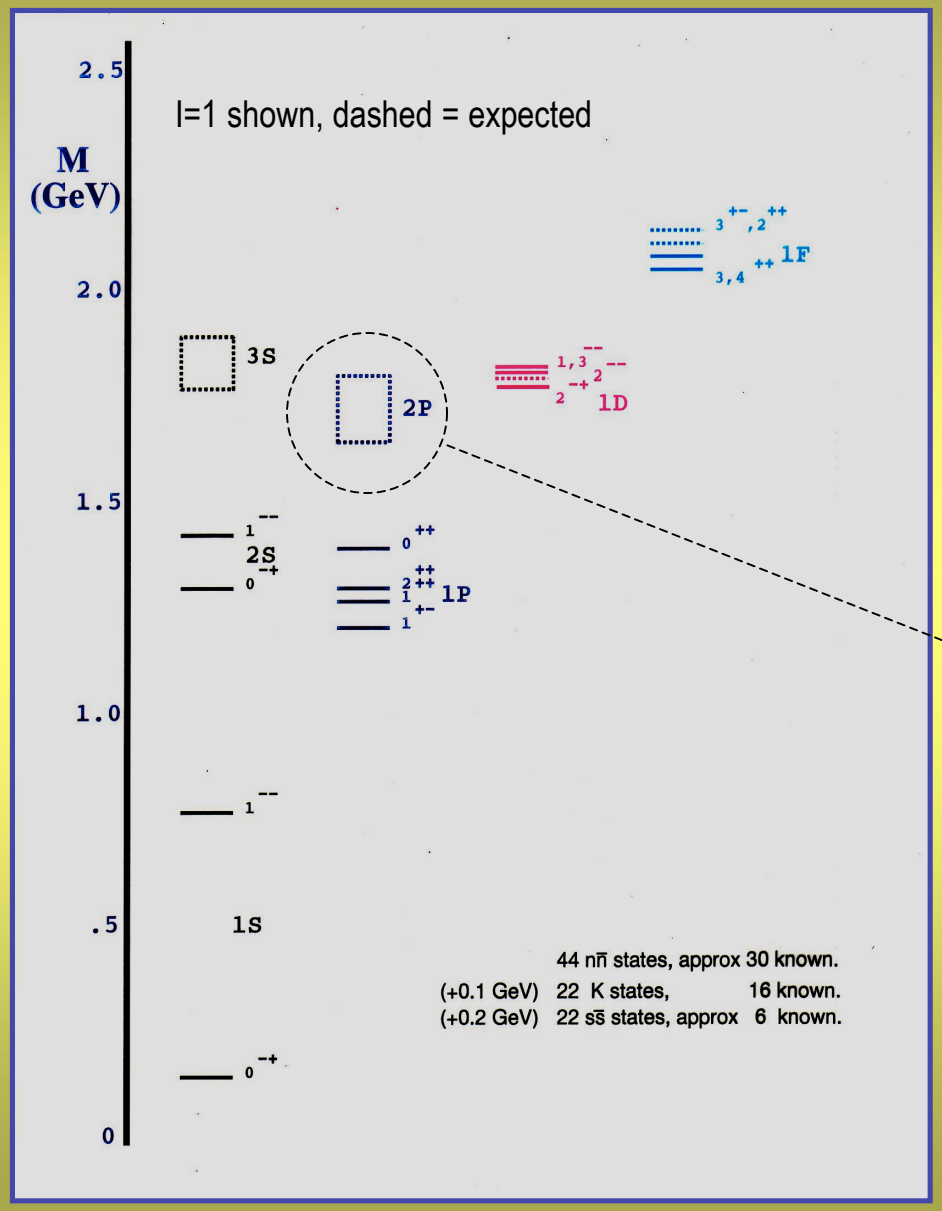
$|gg\rangle$ +… glueballs

Assuming there isn't large mixing, how can we distinguish these different types of states?

One possibility was suggested by WA102.

It also implies something interesting about the pomeron.

Quarkonia



Approx. status, light (u,d,s) $q\underline{q}$ spectrum to ca. 2.1 GeV.

Well known to ca. 1.5 GeV, poorly known above (except for larger-J).

n.b. $s\underline{s}$ is poorly known generally... an argument for $K^{-}p$

Several recent candidates, e.g. $a_1(1700)$, $a_2(1750)$.

Strong decays give M, G, J^{PC} of $q\underline{q}$ candidates.

$q\bar{q}$ mesons quantum numbers

Parity $P_{q\bar{q}} = (-1)^{(L+1)}$ C-parity $C_{q\bar{q}} = (-1)^{(L+S)}$

The resulting $q\bar{q}$ NL states $N^{2S+1}L_J$ have J^{PC} =

1S: $^3S_1$ 1^{--} ; $^1S_0$ 0^{-+} 2S: 2^3S_1 1^{--} ; 2^1S_0 0^{-+} …

1P: $^3P_2$ 2^{++} ; $^3P_1$ 1^{++} ; $^3P_0$ 0^{++} ; $^1P_1$ 1^{+-} 2P …

1D: $^3D_3$ 3^{--} ; $^3D_2$ 2^{--} ; $^3D_1$ 1^{--} ; $^1D_2$ 2^{-+} 2D …

J^{PC} forbidden to $q\bar{q}$ are called

J^{PC}-exotic quantum numbers:

0^{--} ; 0^{+-}, 1^{-+}, 2^{+-}, 3^{-+}, …

Plausible J^{PC}-exotic candidates =

hybrids, glueballs (high mass), maybe multiquarks (fall-apart decays).

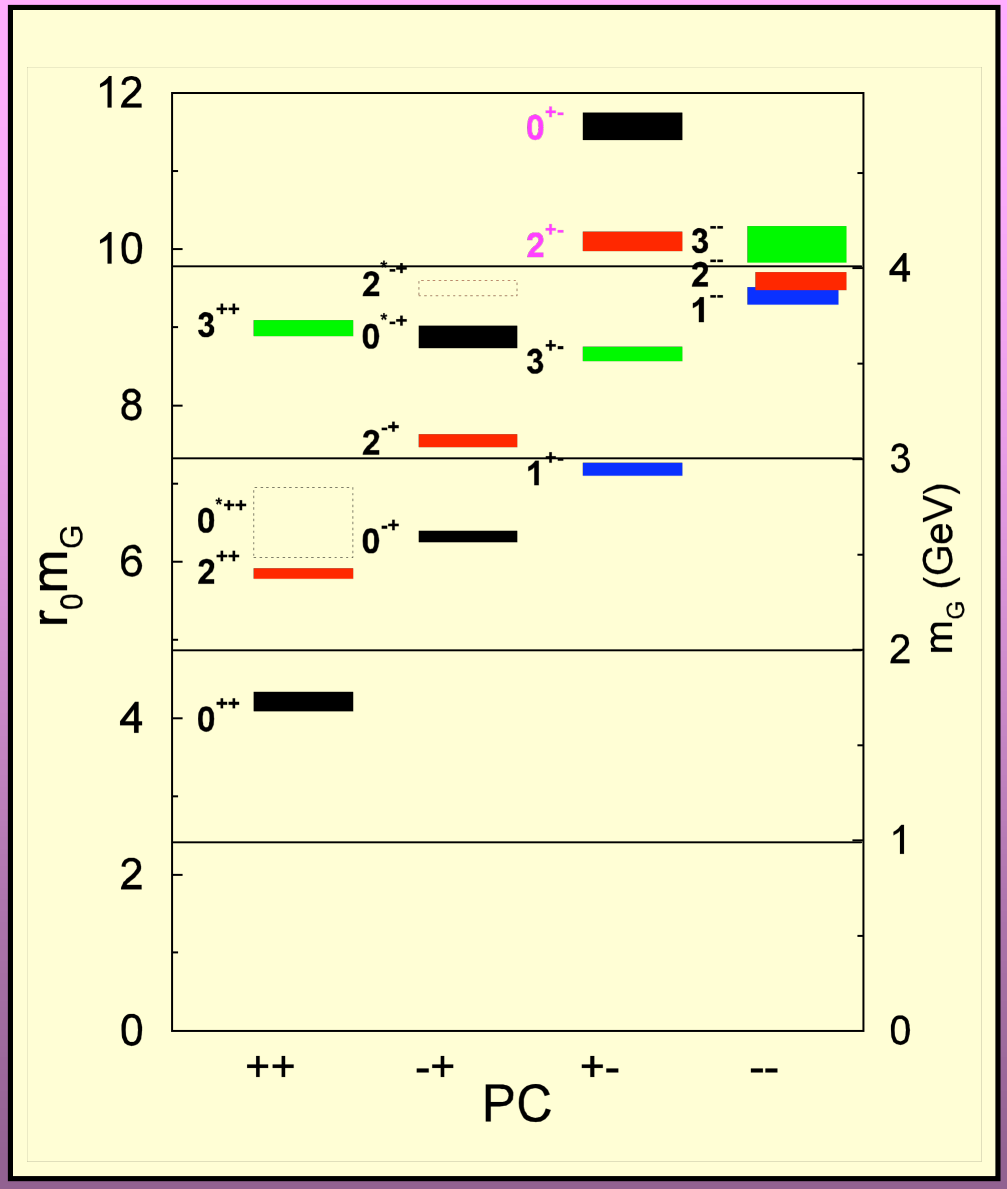
Glueballs

Theor. masses (LGT)

The glueball spectrum from an anisotropic lattice study

Colin Morningstar, Mike Peardon
Phys. Rev. D60 (1999) 034509

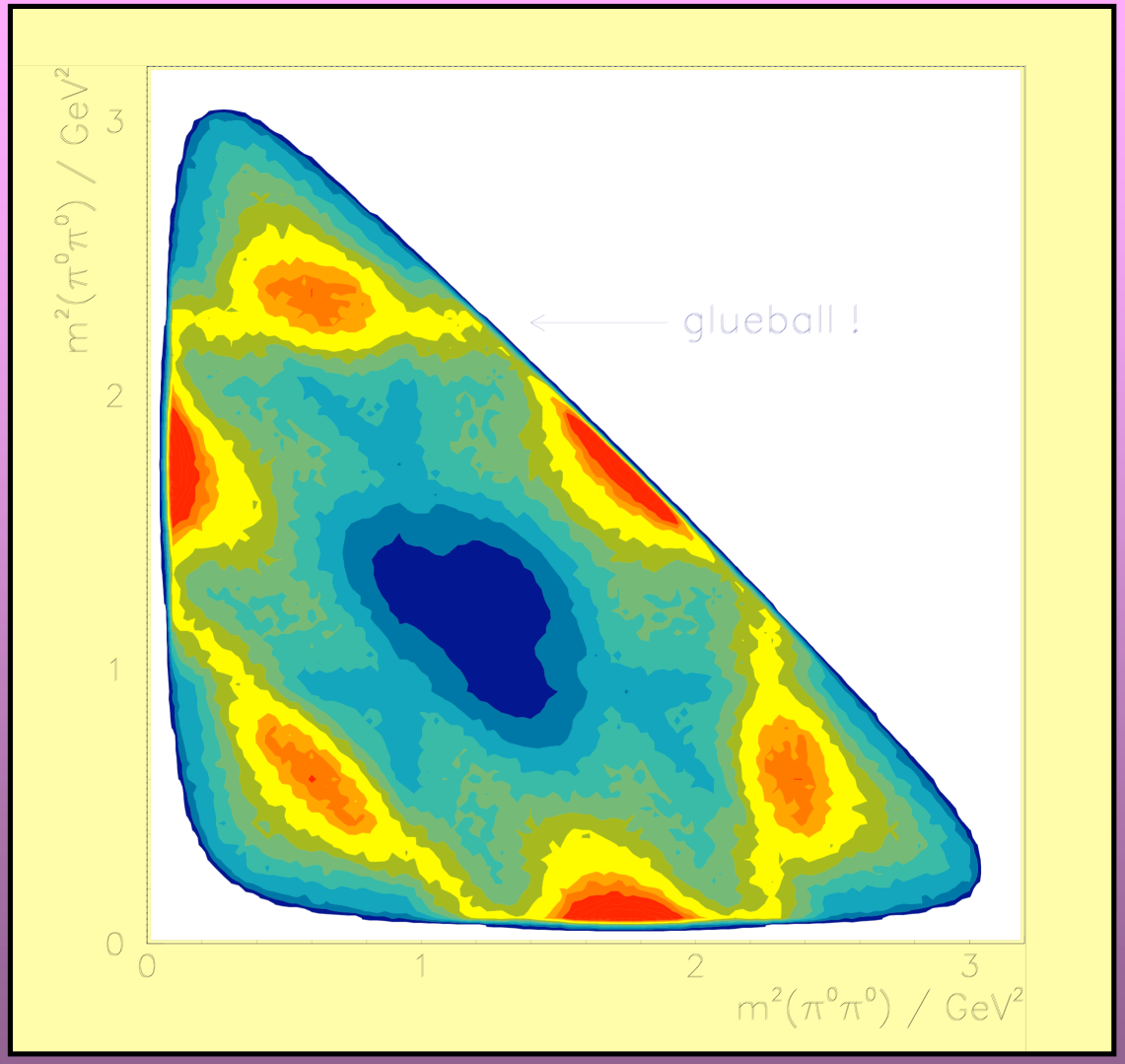
The spectrum of glueballs below 4 GeV in the SU(3) pure-gauge theory is investigated using Monte Carlo simulations of gluons on several anisotropic lattices with spatial grid separations ranging from 0.1 to 0.4 fm.



Glueball discovery? Crystal Barrel expt. (LEAR@CERN, ca. 1995)

$p\bar{p} \rightarrow \pi^0 \pi^0 \pi^0$

Evidence for a scalar resonance,
$f_0(1500) \rightarrow \pi^0 \pi^0$



n.b.
Some prefer a different scalar,
$f_0(1710) \rightarrow \eta\eta,\ K\bar{K}$.

PROBLEM: Neither f_0 decays in a naïve glueball flavor-symmetric way to $\pi\pi$, $\eta\eta$, $K\bar{K}$.
$q\bar{q}$ <–> G mixing?

$\xi(2230) = G / s\bar{s}$ brou ha ha

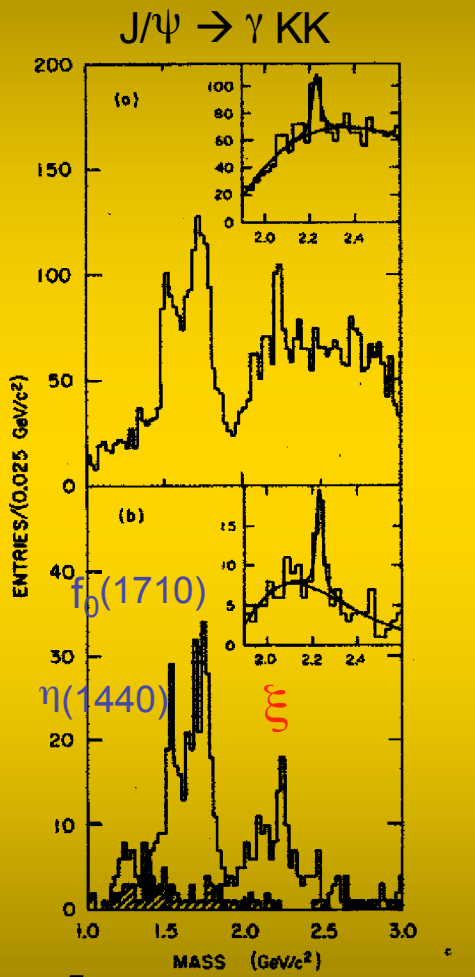


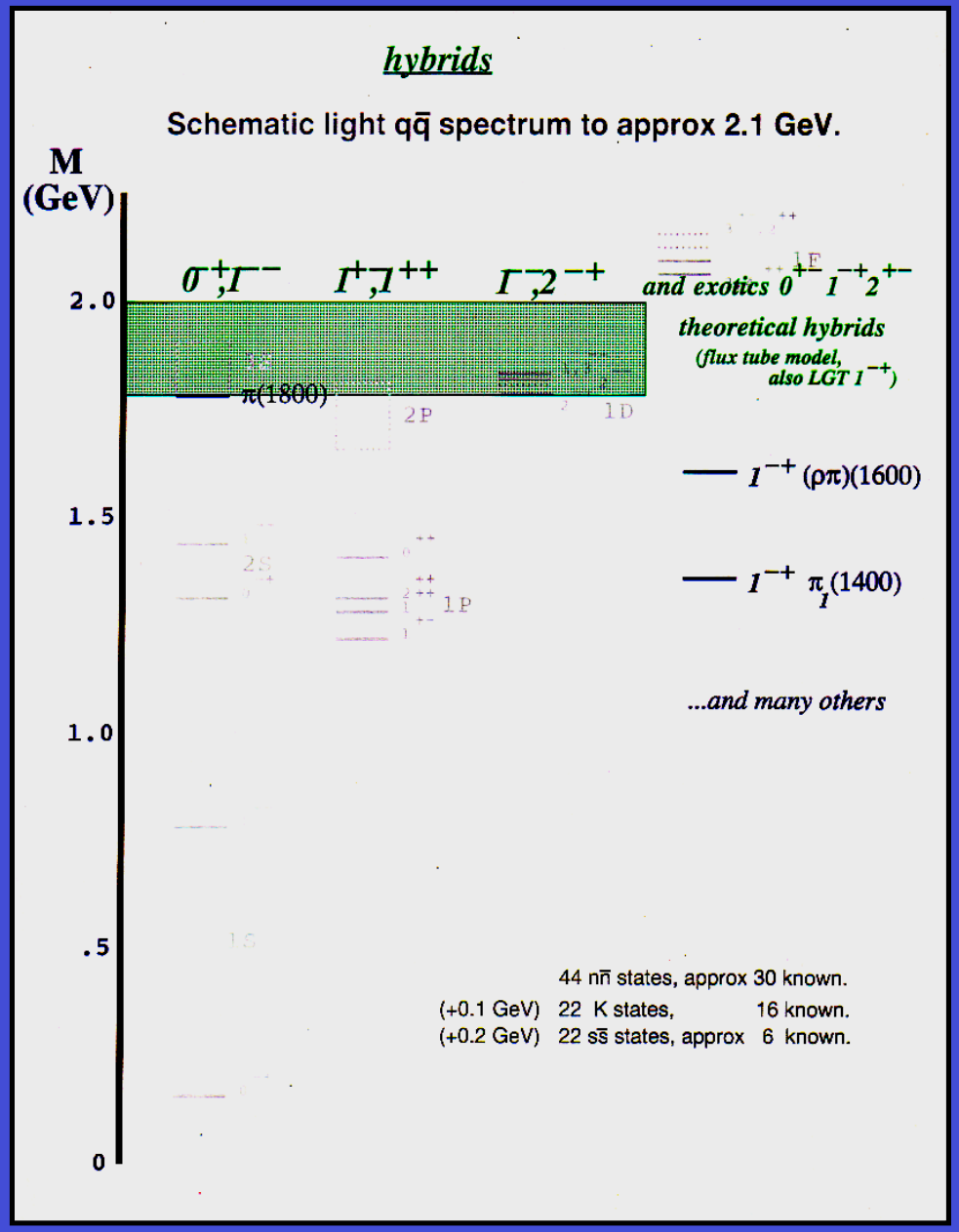
FIG. 1. $K\bar{K}$ invariant-mass distribution for the full sample of 5.8×10^6 J/ψ for (a) the K^+K^- final state and for (b) the $K^0_SK^0_S$ final state, where the four-pion background is shown crosshatched. Fits to the 1.9–2.6-GeV/c^2 mass region are displayed in the insets.

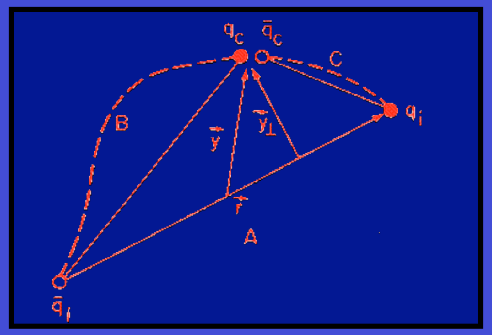
Tensor glueball candidate?

Originally reported by Mark III at SLAC;
R.M.Baltrusaitis et al., PRL56, 107 (1986).

Not seen by DM2 with better statistics.
Claimed by BES (?) but status unclear.

Hybrids:





New band of meson excitations predicted, starting at ca. 1.9 GeV.

Flavor nonets x 8 J^{PC} = 72 states.

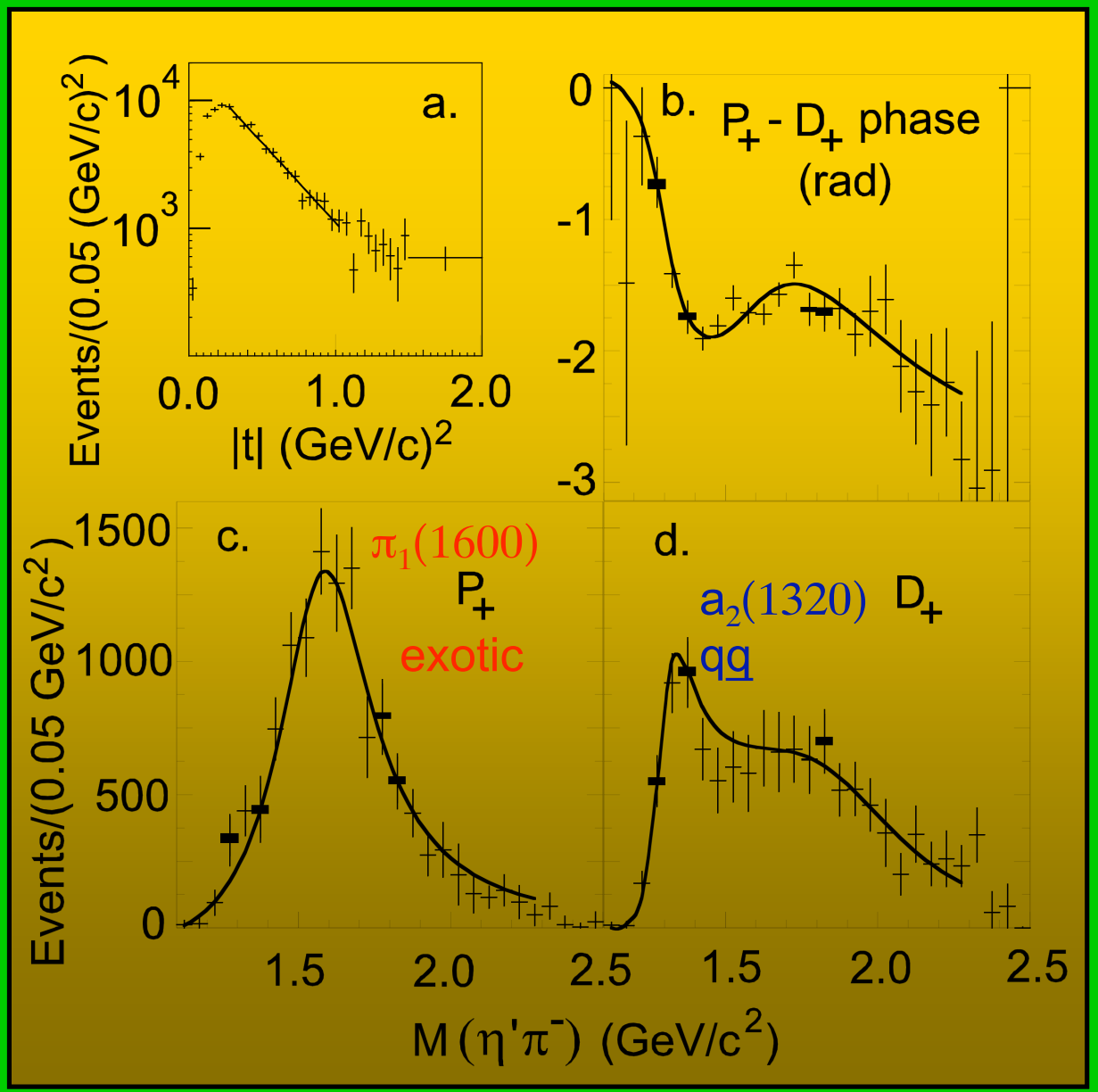
Includes 0^{+-}, 1^{-+} and 2^{+-} J^{PC}-exotics.

Expt Hybrid mesons? The current best signal for a $J^{PC} = 1^{-+}$ **exotic**. (Can't be $q\bar{q}$.) E852@BNL, ca. 1996

$\pi^- p \rightarrow (\pi^- \eta') p$

(Current best of several reactions and claimed exotics.)

Follow up expts planned at CEBAF; "HallD" or GlueX. (photoprod.)



$\pi_2(2000)$ hybrid; $b_1\pi$ mode

A	B, C	L	Γ	A	B, C	L	Γ	A	B, C	L	Γ
2^{-+}	$f_2(1270)\pi$	S	40	1^{+-}	$a_2(1320)\pi$	P	175	1^{-+}	$f_1(1285)\pi$	S	40
		D	20		$a_1(1260)\pi$	P	90			D	20
	$b_1(1235)\pi$	D	40		$h_1(1170)\pi$	P	175		$b_1(1235)\pi$	S	150
	$a_2(1320)\eta$	S	~ 40		$b_1(1235)\eta$	P	150			D	20
	$K_2^*(1430)K$	S	~ 30		$K_2^*(1430)K$	P	60		$a_1(1260)\eta$	S	50
2^{+-}	$a_2(1320)\pi$	P	200		$K_1(1270)K$	P	250		$K_1(1270)K$	S	20
	$a_1(1260)\pi$	P	70		$K_0^*(1430)K$	P	70		$K_1(1400)K$	S	~ 125
	$h_1(1170)\pi$	P	90	1^{++}	$f_2(1270)\pi$	P	175	0^{-+}	$f_2(1270)\pi$	D	20
	$b_1(1235)\eta$	P	~ 15		$f_1(1285)\pi$	P	150		$f_0(1300)\pi$	S	~ 150
0^{+-}	$a_1(1260)\pi$	P	700		$f_0(1300)\pi$	P	~ 20		$K_0^*(1430)K$	S	~ 200
	$h_1(1170)\pi$	P	125		$a_2(1320)\eta$	P	50	1^{--}	$a_2(1320)\pi$	D	50
	$b_1(1235)\eta$	P	80		$a_1(1260)\eta$	P	90		$a_1(1260)\pi$	S	150
	$K_1(1270)K$	P	600		$K_2^*(1430)K$	P	~ 20			D	20
	$K_1(1400)K$	P	150		$K_1(1270)K$	P	40		$K_1(1270)K$	S	40
					$K_1(1400)K$	P	~ 20		$K_1(1400)K$	S	~ 60

F.E.Close and P.R.Page, NPB443, 233 (1995).

***Close and Page**: some notably narrow **nonexotic hybrids** in the f-t model*

Table 4: As in table 3 but for initial hybrid $\sqrt{\frac{1}{2}}(u\bar{u}+d\bar{d})$.

A	B, C	L	Γ	A	B, C	L	Γ	A	B, C	L	Γ
2^{-+}	$a_2(1320)\pi$	S	125	2^{+-}	$b_1(1235)\pi$	P	250	1^{++}	$a_2(1320)\pi$	P	500
		D	60		$h_1(1170)\eta$	P	30		$a_1(1260)\pi$	P	450
	$f_2(1270)\eta$	S	~ 50	0^{+-}	$b_1(1235)\pi$	P	300		$f_2(1270)\eta$	P	70
	$K_2^*(1430)K$	S	~ 30		$h_1(1170)\eta$	P	90		$f_1(1285)\eta$	P	60
1^{+-}	$b_1(1235)\pi$	P	500		$K_1(1270)K$	P	600		$K_2^*(1430)K$	P	~ 20
	$h_1(1170)\eta$	P	175		$K_1(1400)K$	P	150		$K_1(1270)K$	P	40
	$K_2^*(1430)K$	P	60	1^{-+}	$a_1(1260)\pi$	S	100		$K_1(1400)K$	P	~ 20
	$K_1(1270)K$	P	250			D	70	0^{-+}	$a_2(1320)\pi$	D	60
	$K_0^*(1430)K$	P	70		$f_1(1285)\eta$	S	50		$f_0(1300)\eta$	S	~ 200
1^{--}	$K_1(1270)K$	S	40		$K_1(1270)K$	S	20		$K_0^*(1430)K$	S	~ 200
	$K_1(1400)K$	S	60		$K_1(1400)K$	S	~ 125				

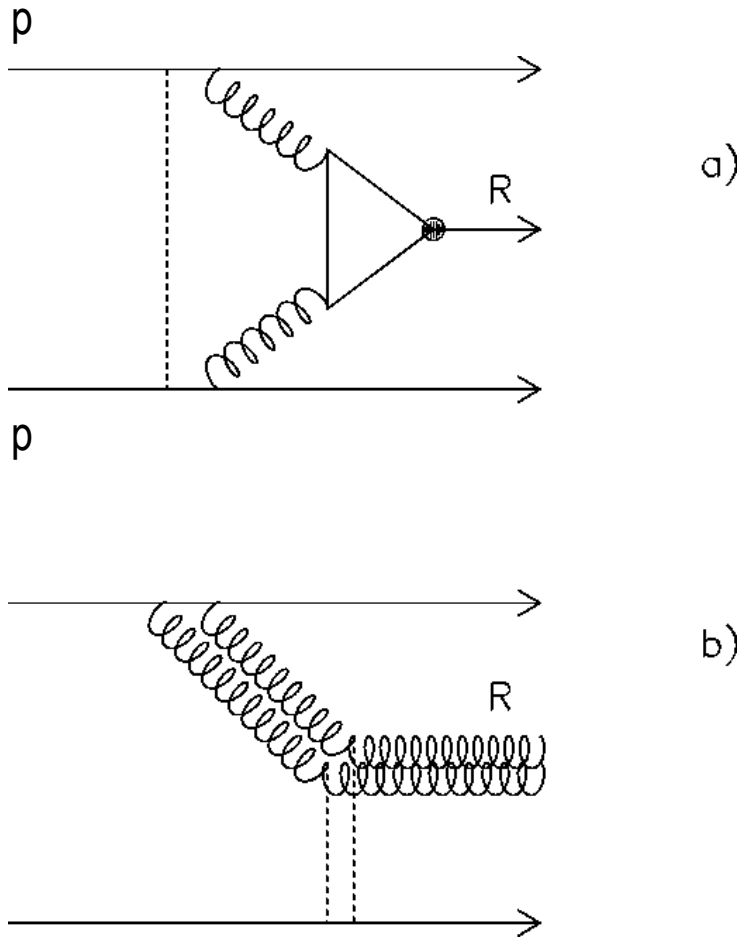
$\omega(2000)$ hybrid

WA102

Central meson production
CERN SPS, p_{beam} = 450 GeV

ca. 10 papers by WA102 Collaboration
and by F.E.Close and A.Kirk

AK and FEC, hep-ph/9701222,
PLB397, 333 (1997) (most cited).

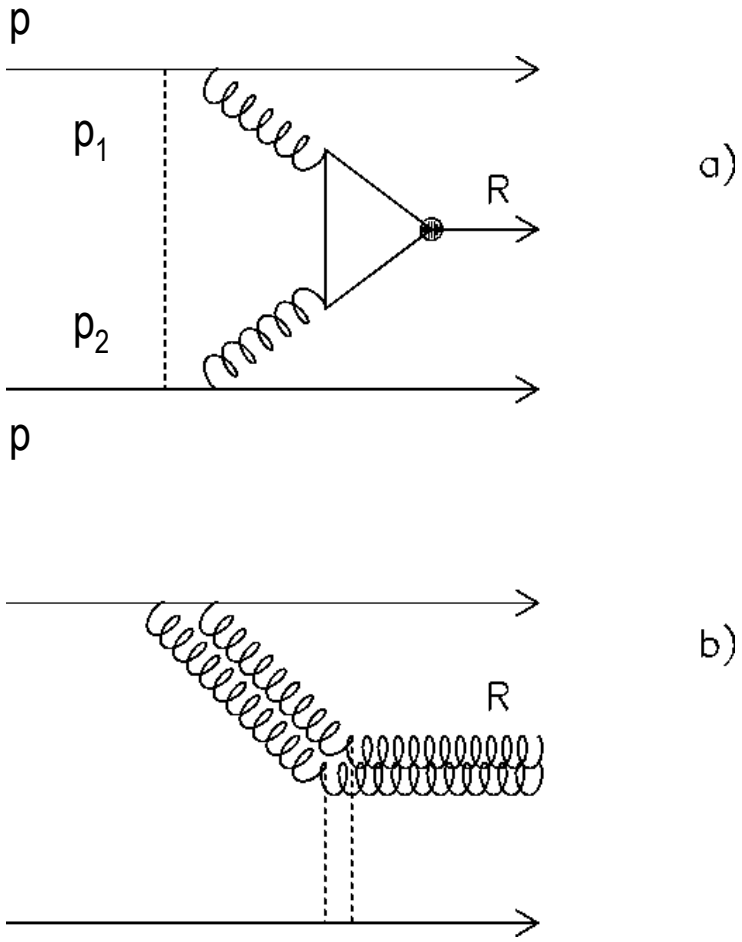


WA102

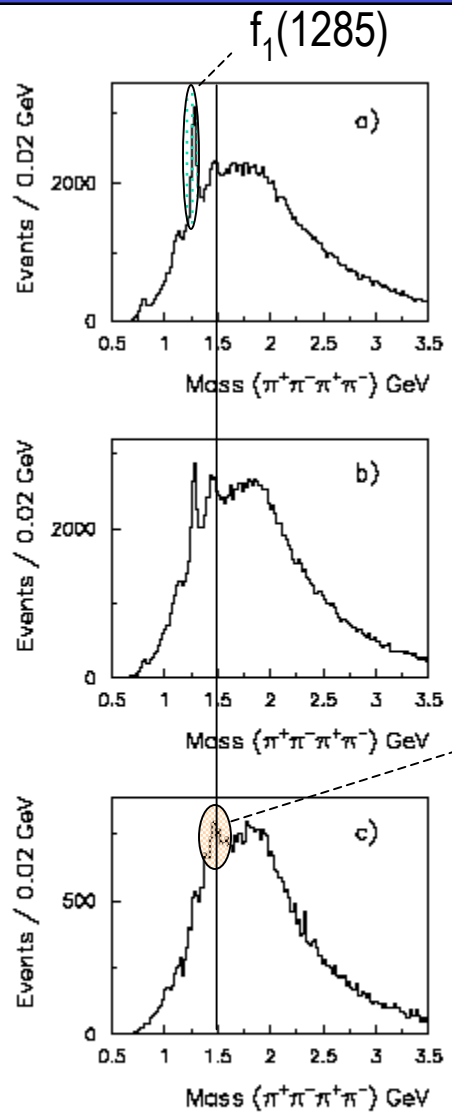
Central meson production

G and qq̄ candidates were strongly distinguished by cuts on exchanged $|p_1 - p_2|_{cm}$, "**dP_T**". and by differential production cross dependence on an azimuthal angle ϕ.

Quantum numbers of the "pomeron"?
It acts like 1^- exchange rather than 0^+.



[1] dP_T is the difference in the transverse momentum vectors of the two exchange Pomerons and ϕ is the angle between the transverse momentum vectors, p_T, of the two outgoing protons.



$dP_T > 0.5$ GeV.

Strong $q\bar{q}$ $f_1(1285)$, weak G? $f_0(1500)$

0.2 GeV $< dP_T < 0.5$ GeV.

$dP_T < 0.2$ GeV.

Vy weak $q\bar{q}$ $f_1(1285)$, stronger G? $f_0(1500)$

Figure 3: The 4π mass spectra (i) With $dP_T > 0.5$ GeV exhibiting a clear $f_1(1285)$; (ii) $0.2 < dP_T < 0.5$ GeV (iii) $dP_T < 0.2$ GeV where the $f_1(1285)$ has disappeared while the $f_0(1500)$ is seen more clearly.

$\pi^+\pi^-\pi^+\pi^-$

F.E.Close and A.Kirk, hep-ph/9701222 PLB397, 333 (1997).

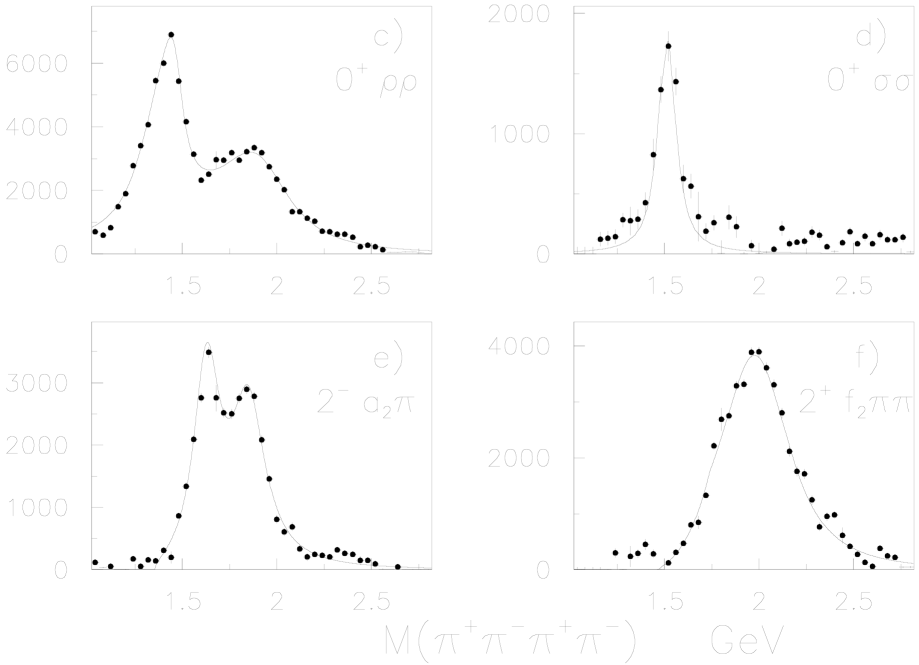
WA102…

D.Barberis et al.
hep-ex/0001017
PLB474, 423 (2000).

Central meson production… glueballs and hybrids?

$f_0(1500) \rightarrow 4\pi$

Scalar glueball candidate



$\eta_2(1870)$
nonexotic hybrid?
(S+P decay mode)

2^{-+} **overpopulation**
$\eta_2(1645)$ **and** $\eta_2(1870)$
$\rightarrow a_2\pi$

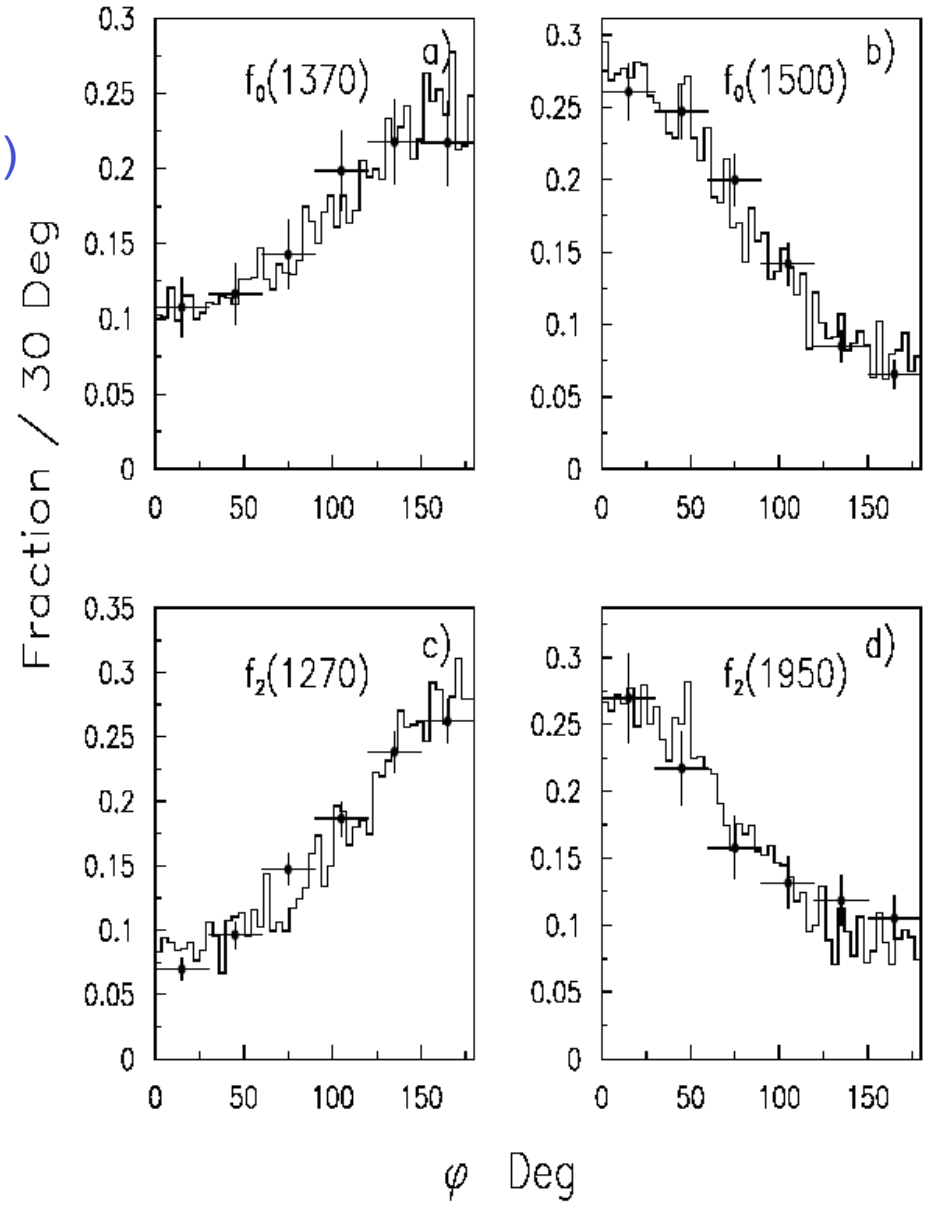
$f_2(1950) \rightarrow f_2\pi\pi$

Tensor glueball candidate?

Dependence of the production cross section on the azimuthal angle ϕ.
(hep-ph/0001158)

0^{++} $q\bar{q}$ state (?)
$f_0(1370)$

2^{++} $q\bar{q}$ state
$f_2(1270)$



0^{++} glueball candidate $f_0(1500)$

New 2^{++} glueball candidate $f_2(1950)$

References:

1. hep-ph/0106108
Title: Large Isospin mixing in phi radiative decay and the spatial size of the f0(980)- a0(980) meson
Authors: F.E. Close, A. Kirk
Comments: 7 pages, Latex
Journal-ref: Phys.Lett. B515 (2001) 13-16

2. hep-ph/0103173
Title: Scalar Glueball-qqbar Mixing above 1 GeV and implications for Lattice QCD
Authors: F.E. Close, A. Kirk
Comments: 33 pages, Latex, 4 Figures
Journal-ref: Eur.Phys.J. C21 (2001) 531-543

3. hep-ph/0008066
Title: Isospin breaking exposed in f0(980)- a0(980) mixing
Authors: F.E. Close, A. Kirk
Comments: 11 pages, Latex, 3 Figures
Journal-ref: Phys.Lett. B489 (2000) 24-28

4. hep-ph/0004241
Title: The mixing of the f0(1370), f0(1500) and f0(1710) and the search for the scalar glueball
Authors: F.E. Close, A. Kirk
Comments: 15 pages, Latex, 2 Figures
Journal-ref: Phys.Lett. B483 (2000) 345-352

5.hep-ph/0001158
Title: Dynamics of Glueball and qqbar production in the central region of pp collisions Authors: F.E. Close, A. Kirk, G. Schuler
Comments: 12 pages, Latex, 4 Figures typographical error in equation (2) corrected Journal-ref: Phys.Lett. B477 (2000) 13-18

6.hep-ph/9706543
Title: Implications of the Glueball-qqbar filter on the 1++ nonet
Authors: Frank E. Close, Andrew Kirk
Comments: 21 pages, Latex, 5 Figures
Journal-ref: Z.Phys. C76 (1997) 469-474

7.hep-ph/9701222
Title: A Glueball- $q\bar{q}$ Filter in Central Hadron Production
Authors: Frank Close, Andrew Kirk
Comments: Latex file. 5 figs including 2 from WA102 CERN report "A kinematical selection of glueball candidates in central production"
Journal-ref: Phys.Lett. B397 (1997) 333-338